DIGITAL IMAGE PROCESSING & MACHINE VISION (MC-541)

BY

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KINGDOM OF PIXELONIA

- **The Tale of the Magical Painter: The Art of Digital Images**
  - Once upon a time, in a vibrant kingdom called **Pixelonia**, everything people saw was made up of tiny, colorful squares called **pixels**. These pixels combined to create stunning pictures of landscapes, portraits, and even memories of the past. But not all images were perfect—some were blurry, noisy, or faded. To solve this problem, the wise ruler of Pixelonia called upon the **Magical Painter**, a digital wizard with incredible tools to make images clearer, sharper, and more beautiful.

THE CANVAS OF PIXELS

- The Magical Painter explained that every image started as a blank **canvas of pixels**. Each pixel had a special code made of numbers, representing its **color and intensity**.
  - **Grayscale Images**: Some canvases were simple, where each pixel had a number between 0 (black) and 255 (white). These were **black-and-white images**.
  - **Color Images**: Others were colorful, where each pixel was made of three magic colors: **Red, Green, and Blue (RGB)**. By mixing these colors, the Painter could create millions of shades.
  - "Every image you see," the Painter said, "is just a collection of these tiny pixels working together."

THE WIZARD'S TOOLBOX

THE MAGICAL PAINTER'S WORKSHOP WAS FULL OF FASCINATING TOOLS FOR WORKING WITH IMAGES.

- **Enhancing the Picture**:
  - The Painter used tools like **contrast adjustment** to brighten dull images and **sharpening filters** to make blurry edges crisp.
  - To fix dim photos, he applied **histogram equalization**, which magically spread out the pixel values to reveal hidden details.
- **Cleaning the Canvas**:
  - When dust and noise covered the canvas, the Painter used **filters**:
    - **Smoothing filters** (like mean or Gaussian) gently cleaned noisy images.
    - **Median filters** were especially good at removing "salt and pepper" noise—those random black and white dots.
- **Drawing and Changing Shapes**:
  - To alter shapes, the Painter used **geometric transformations**:
    - **Scaling**: To make the image larger or smaller.
    - **Rotation**: To spin the image to any angle.
    - **Translation**: To move the image around the canvas.
- **Detecting Hidden Patterns**:
  - With his edge-detection wand, the Painter uncovered hidden patterns in images. Using tools like the **Sobel filter** or **Canny edge detector**, he could find outlines and shapes that were invisible to the naked eye.

THE MYSTERY OF THE FREQUENCY WORLD

- One day, the Painter uncovered a strange portal called the **Frequency Domain**. It was a world where images were no longer pixels but a combination of waves.
- By casting the spell of the **Fourier Transform**, the Painter could see the image's hidden frequencies. He found that:
  - **Low frequencies** carried smooth, large-scale features (like a clear sky).
  - **High frequencies** held fine details (like edges and textures).
- In this world, the Painter used magical masks called **filters** to block unwanted frequencies:
  - **Low-pass filters** smoothed out rough edges.
  - **High-pass filters** enhanced sharp details.

When he returned to Pixelonia, the images he brought back were clearer and more defined than ever before.

RESTORING FADED MEMORIES

- The Painter's greatest challenge came when the ruler of Pixelonia gave him an old, faded portrait. The image was corrupted with cracks and missing parts.
- Using **image restoration**, the Painter:
  - Repaired the cracks using **interpolation and inpainting**.
  - Removed strange distortions caused by lens problems through **geometric corrections**.

Soon, the portrait looked as fresh as the day it was painted.

THE MAGIC OF MACHINE VISION

- In his final adventure, the Magical Painter ventured into the world of **intelligent machines**. He taught machines how to:
  - Recognize faces in an image.
  - Identify objects like cats, cars, and trees.
  - Read text using **Optical Character Recognition (OCR)**.
  - By combining his knowledge of digital image processing with **machine learning**, the Painter gave machines the power to see and understand the world.

THE MORAL OF THE STORY

- The Magical Painter reminded the people of Pixelonia:
  - "Every digital image holds infinite possibilities. With the right tools and techniques, we can transform, enhance, and analyze images to unlock hidden beauty and meaning."
- And so, the kingdom of Pixelonia thrived, with every image brought to life through the art of **Digital Image Processing**.

KEY CONCEPTS IN THE STORY

Story Element	Digital Image Processing Concept
Pixelonia and Pixels	Digital images are made of tiny squares called pixels.
RGB Colors and Grayscale	Images can be in grayscale (0-255) or RGB color format.
Contrast, Sharpening, Filters	Image enhancement techniques.
Geometric Transformations	Scaling, rotation, and translation of images.
Frequency Domain and Fourier	Analyzing images in terms of frequencies.
Restoration and Inpainting	Fixing damaged or corrupted images.
Machine Vision	Using digital image processing for AI and recognition tasks.

COURSE OBJECTIVES

- To understand fundamentals of machine vision and digital image processing
- Be aware of some possibilities and limitations of machine vision and digital image processing
- To have enough theoretical understanding and background to begin practical work with machine vision systems

COURSE OUTLINE (APPROX. 15 SESSIONS INCLUDING A MID TERM)

1. Introduction & Applications of DIP&MV
2. Machine Vision System (scene acquisition, vision sensors, lighting and constraints)
3. Image Pre-Processing (filtering)
4. Image Segmentation
5. Feature Selection for Processing of Images
6. Computation of Feature Characteristics
7. Feature Classification
8. Color Image Processing
9. Pattern Recognition
10. Development of a prototype Machine Vision System with Digital Image Processing application

REFERENCE BOOKS & JOURNALS

- **Digital Image Processing**
  by Rafael C. Gonzalez & Richard E. Woods (2nd Edition), Pearson Education
- **Applied Image Processing**
  by G.W. Awcock & R. Thomas , McGrawHill
- **Fundamental of Digital Image Processing: A Practical Approach with Examples in MATLAB**
  by Solomon and Breckon, Willey & Blackwell (2011)
- **Computer Vision: A Modern Approach**
  by Forsyth & Ponce, Prentice Hall (2003)
- **Digital Image Processing : An Algorithmic Approach with MATLAB**
  by Uvais Qidwai & C.H. Chen, CRC Press (2009)

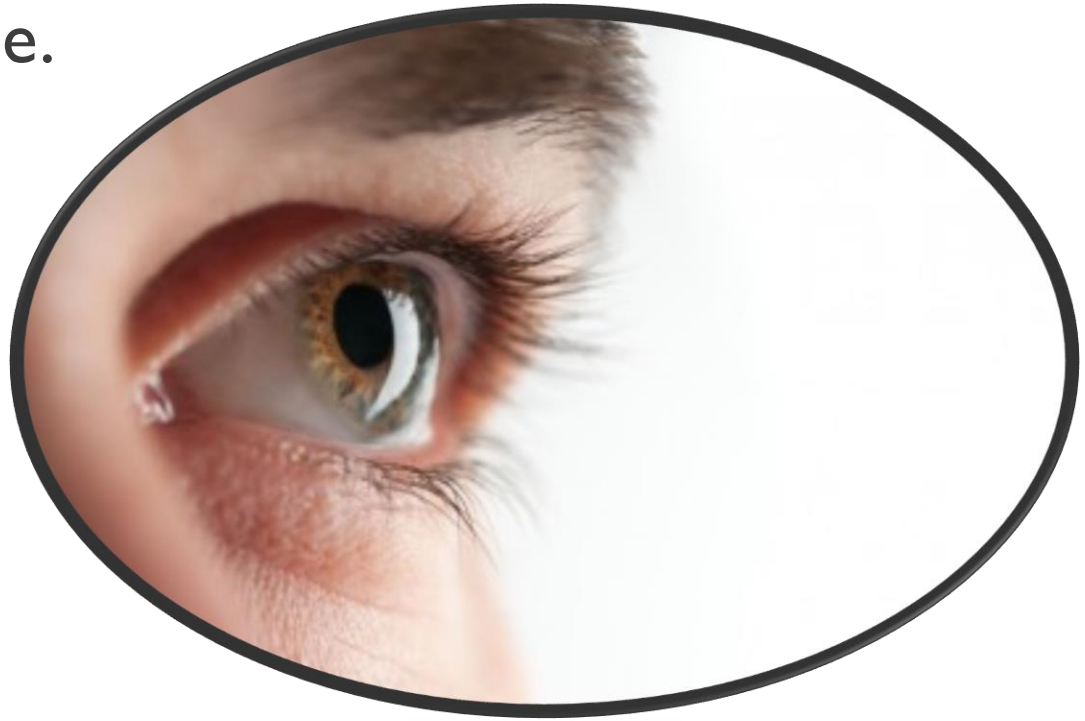
Journals & Magazines

- **Image & Vision Computing, Journal (IVC)**
- **Computer Vision & Image Understanding, Journal (CVIU)**
- **International Journal of Computer Vision (IJCV)**
- **IEEE Transactions on Pattern Analysis & Machine Intelligence (PAMI)**
- **IEEE Transactions on Image Processing**

INTRODUCTION & APPLICATIONS OF DIP & MV

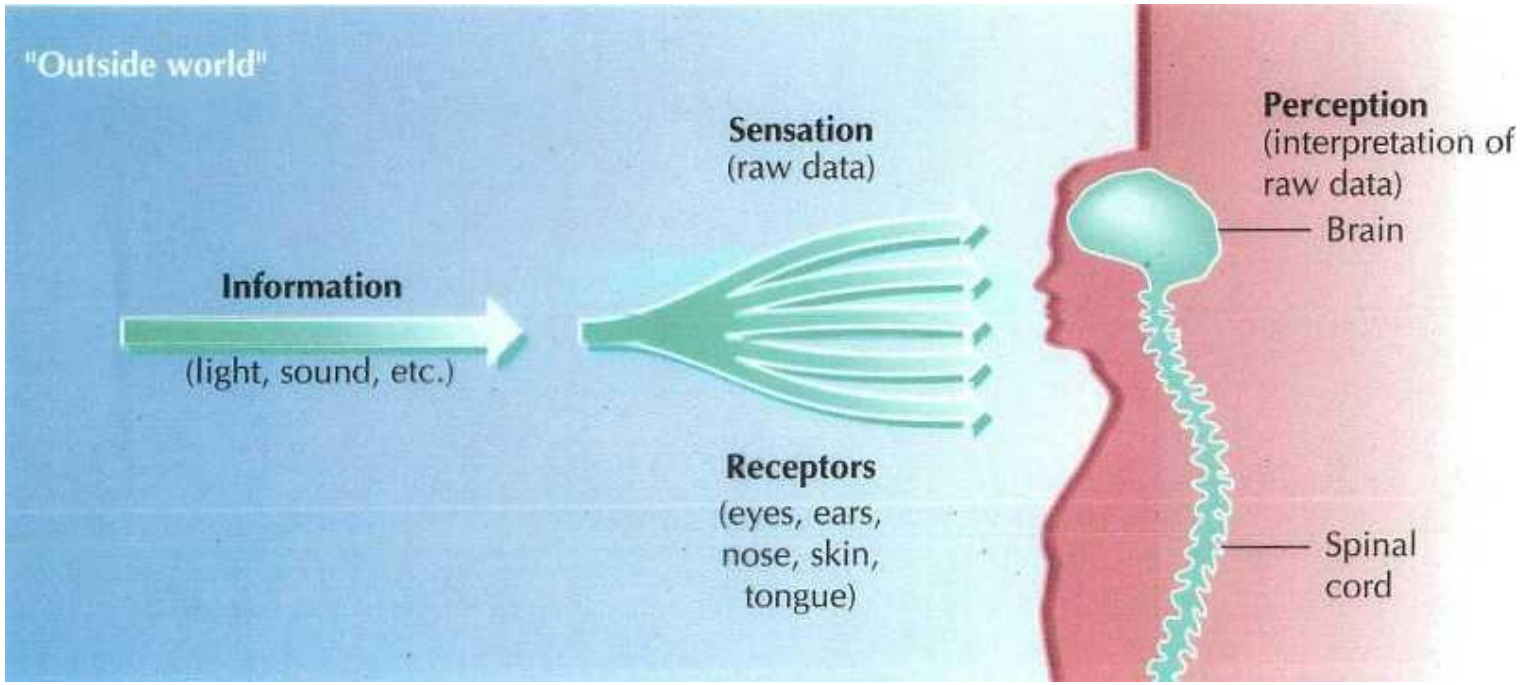
VISION AS A SENSE

- Vision is the most valuable sense.
- It can provide:
  - Absolute and relative position
  - Range
  - Scale
  - Orientation and
  - much more ……

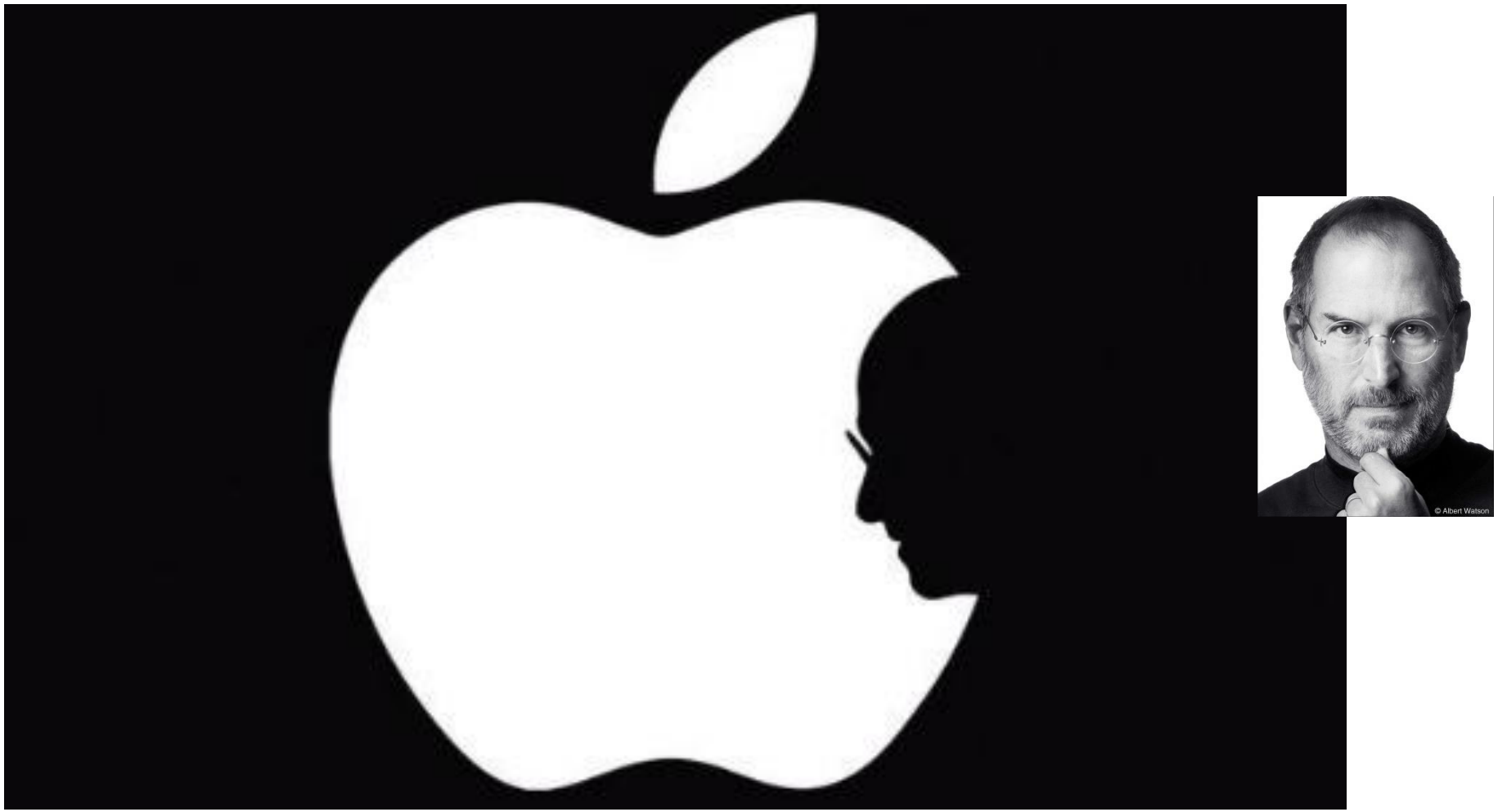


SENSATION & PERCEPTION

- Distinguishing feature of higher order animate vision is the **perception** of images rather than their simple **sensation**

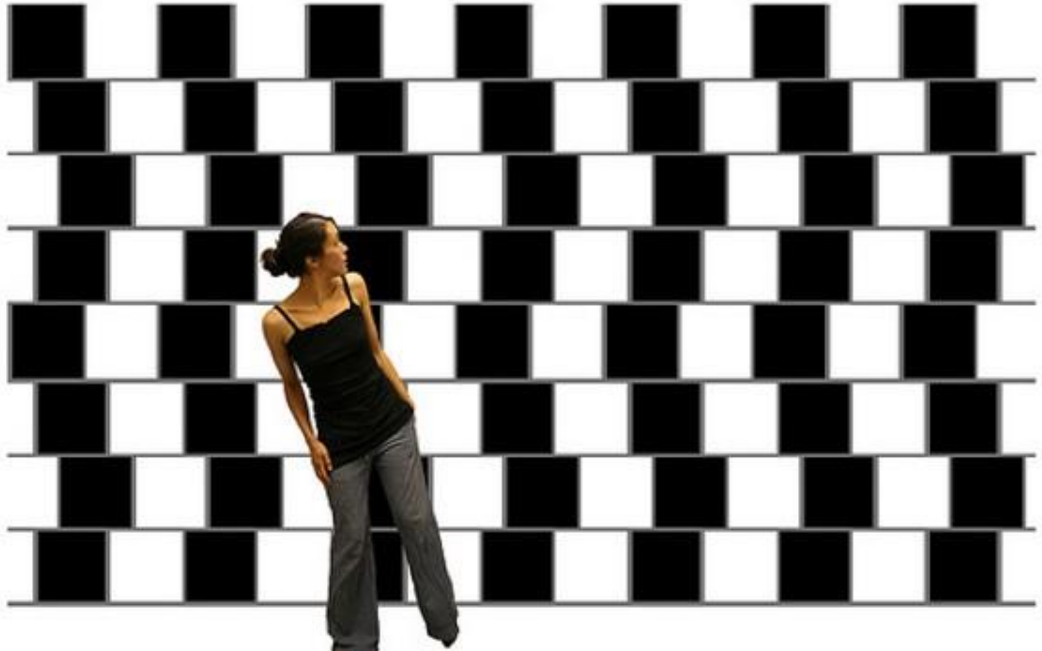


PERCEPTION IS INCOMPLETE WITHOUT KNOWLEDGE-BASE



FROM PERCEPTION TO UNDERSTANDING

- Perception makes image understanding a vital ingredient of any computer vision system



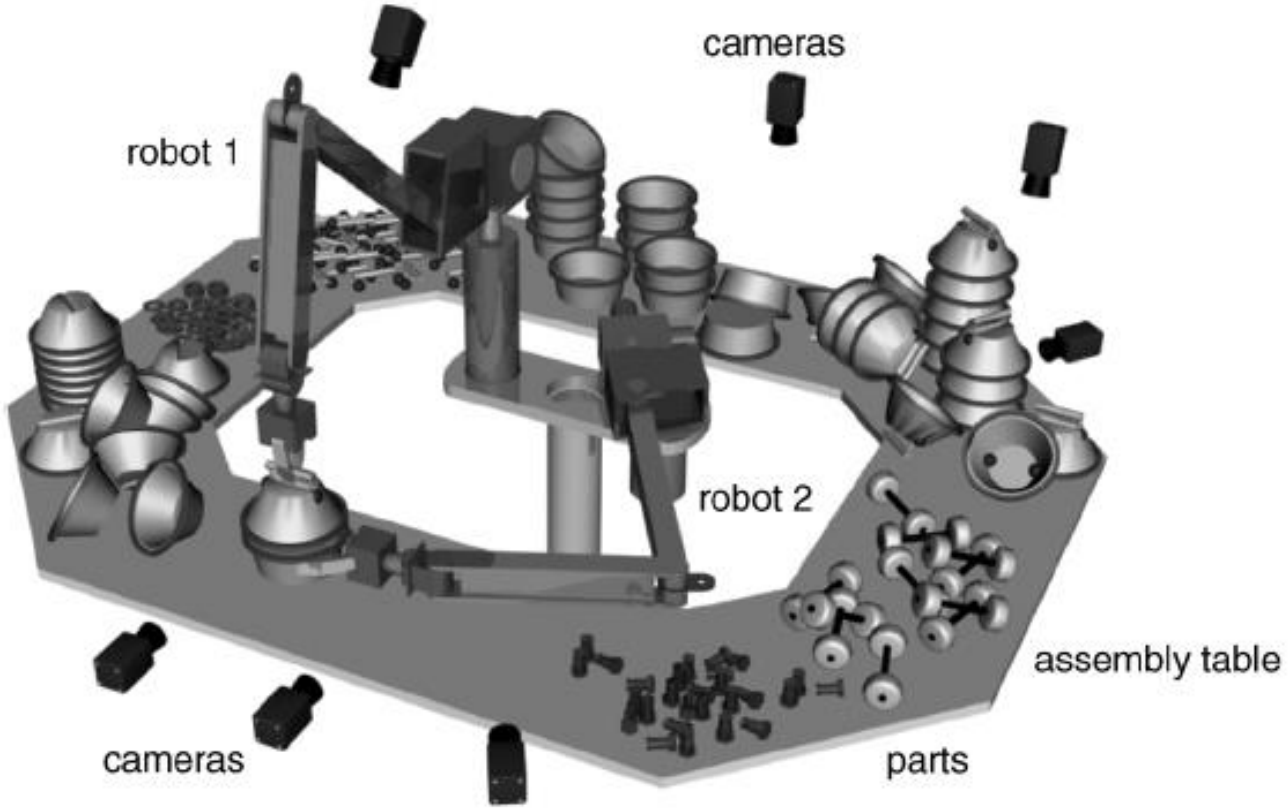
GOAL OF MACHINE VISION

- The goal of Machine Vision is to create a model of the real world from images:
  - A machine vision system recovers useful information about a scene from its two dimensional projections
  - The world is three dimensional
  - Two dimensional digitized images

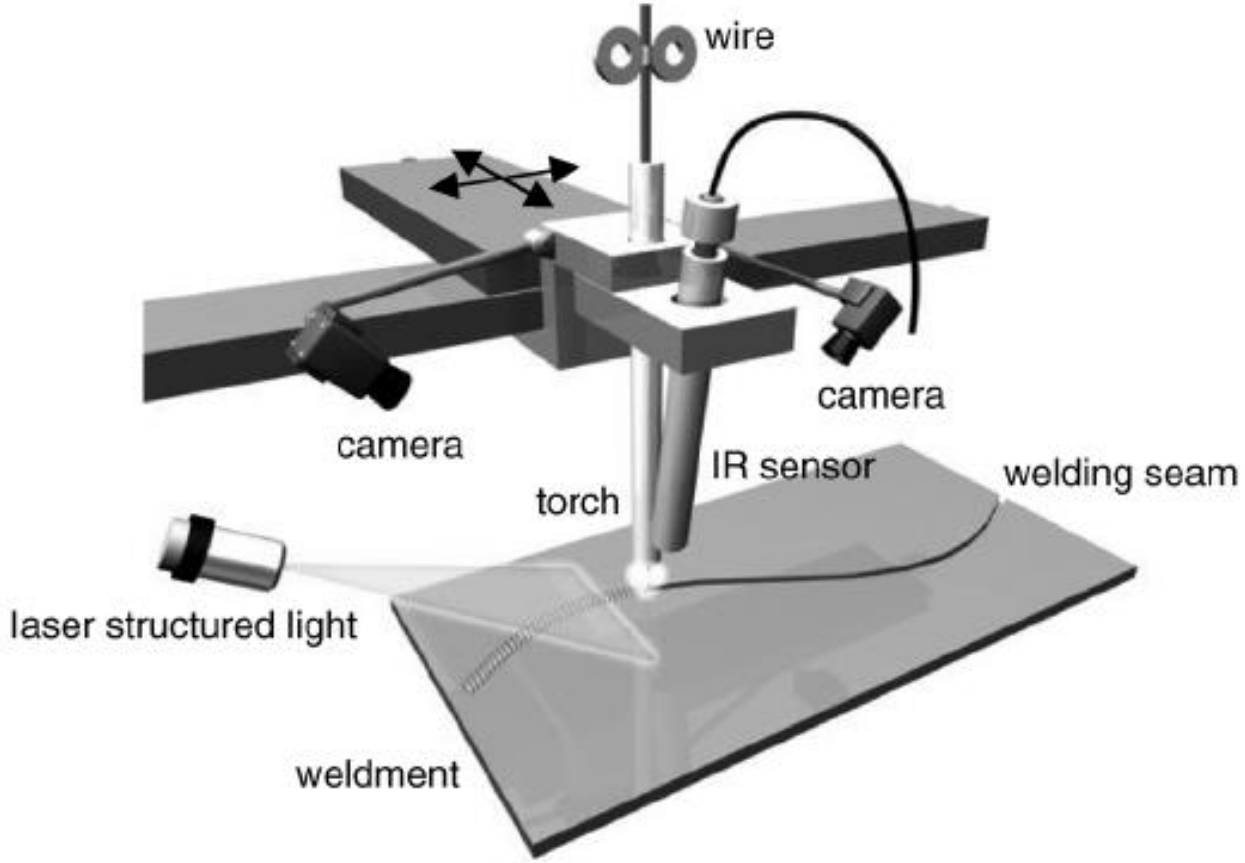
KEY FUNCTION OF MACHINE VISION???

- Associates machine world of computing and electronics with human attribute of vision
  - Computing aspects include hardware elements of optical sensors, parallel processing architectures, computer graphics and displays, software elements of data manipulation and calculation
  - Vision aspects mirror the human visual system and encompass the functional aspects of the eye, optic nerve and brain

INTELLIGENT FLEXIBLE ASSEMBLY STATION



INTELLIGENT WELDING SYSTEM



MACHINE VISION?

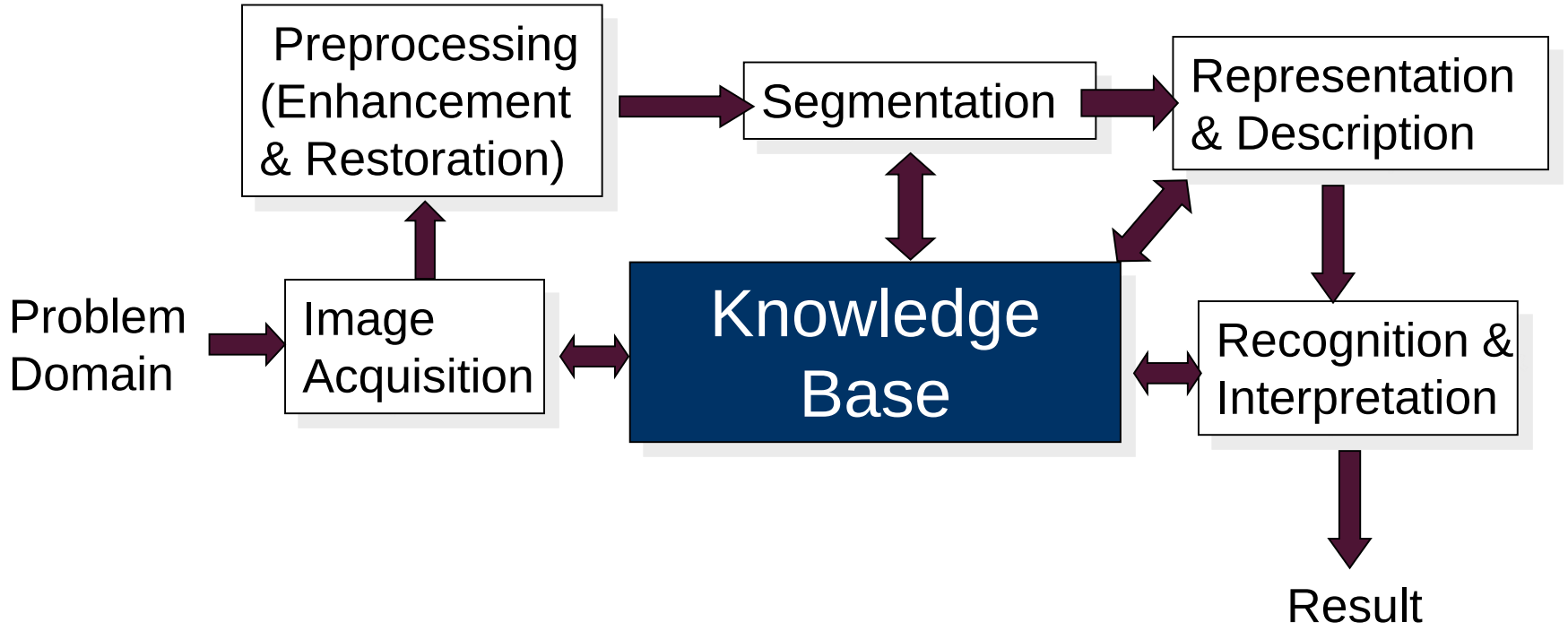
Machine vision is the technology to replace or complement manual inspections and measurements with digital cameras and image processing.

WHY MACHINE VISION?

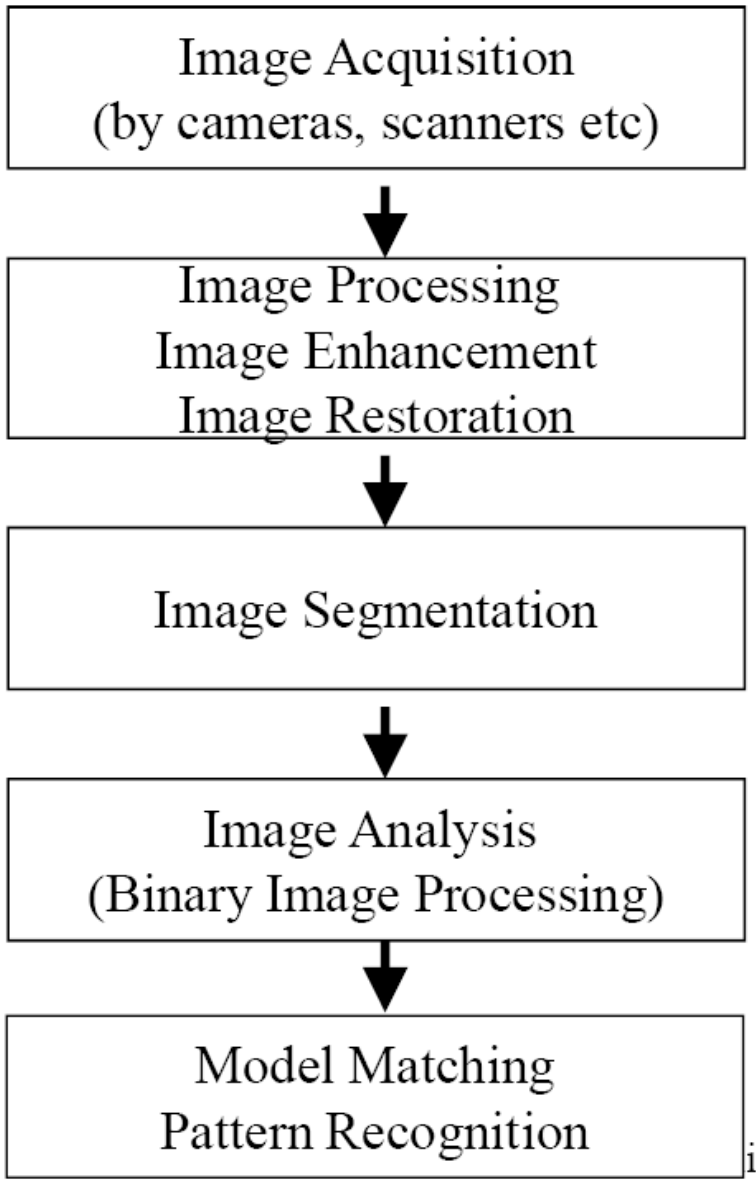
Technology is used in a variety of different industries:

- To automate the production,
- To increase production speed and yield, and
- To improve product quality.

MACHINE VISION SYSTEM FRAMEWORK

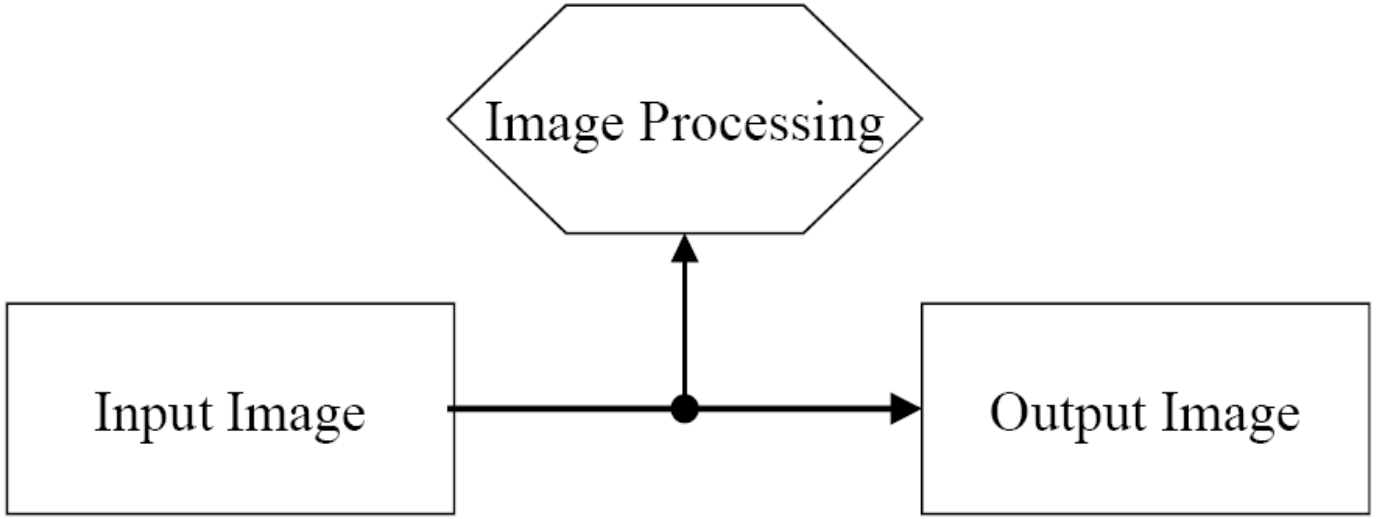


Machine Vision Stages



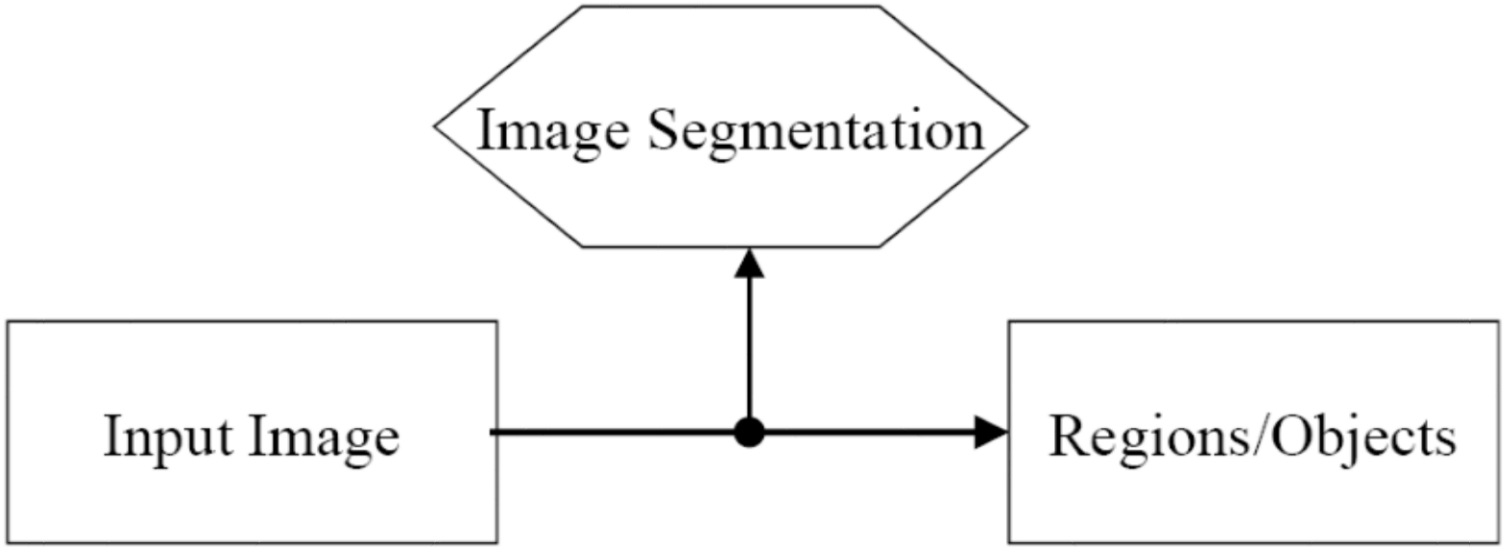
- Analog to digital conversion
- Remove noise/patterns, improve contrast
- Find regions (objects) in the image
- Take measurements of objects/relationships
- Match the above description with similar description of known objects (models)

Image Processing



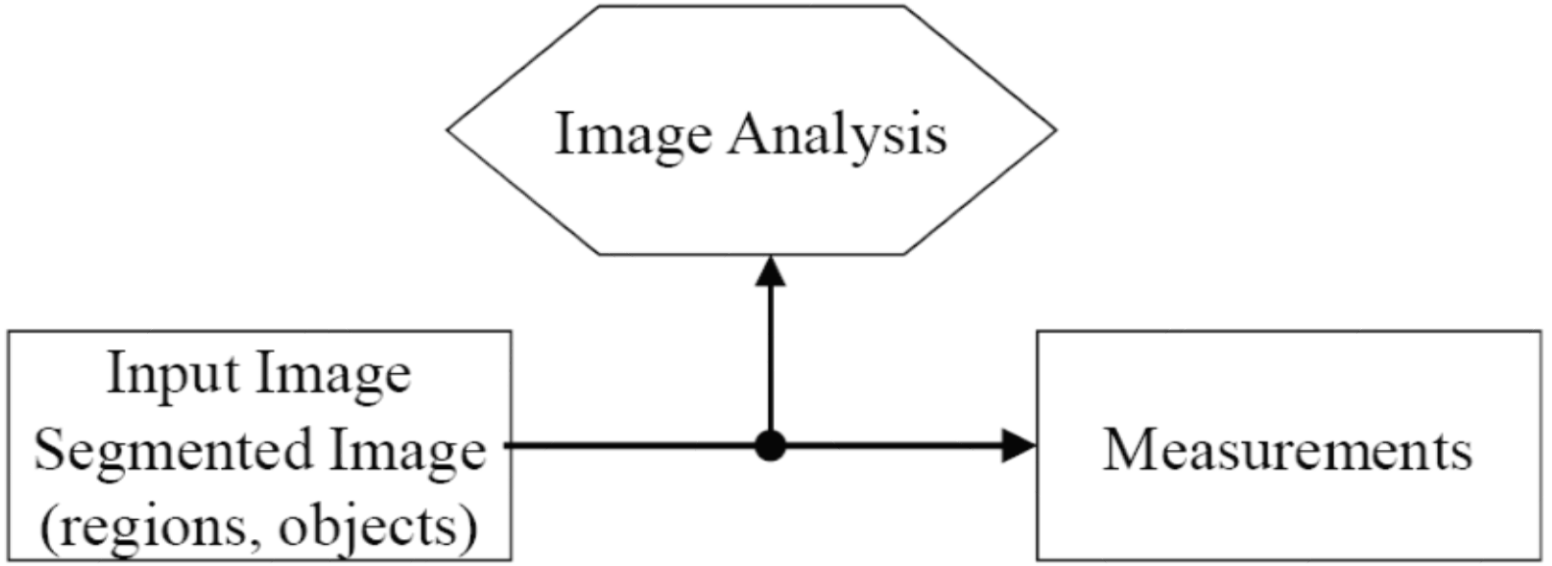
- Image transformation
  - image enhancement (filtering, edge detection, surface detection, computation of depth).
  - Image restoration (remove point/pattern degradation: there exist a mathematical expression of the type of degradation like e.g. Added multiplicative noise, sin/cos pattern degradation etc).

Image Segmentation



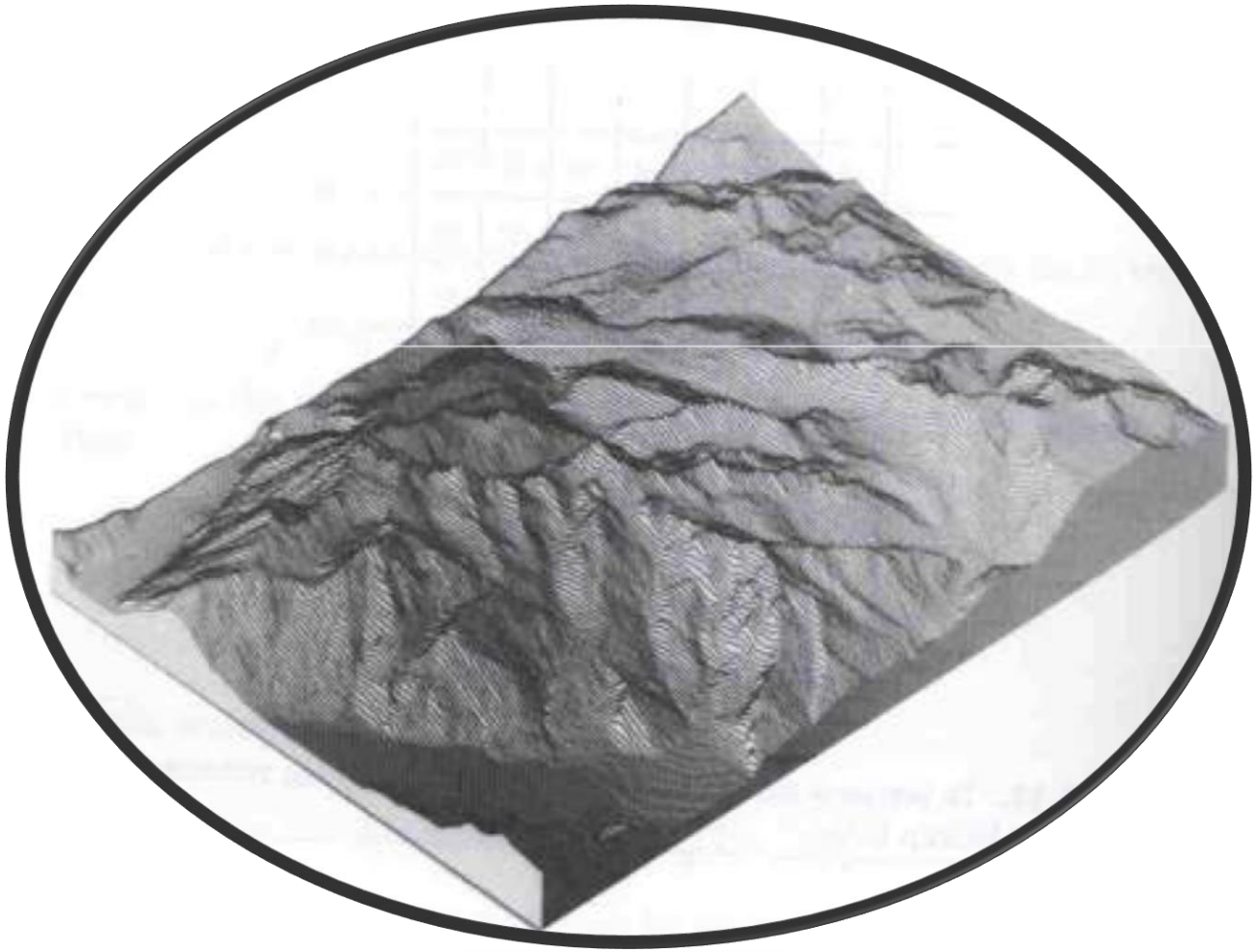
- Classify pixels into groups (regions/objects of interest) sharing common characteristics.
  - Intensity/Color, texture, motion etc.
- Two types of techniques:
  - **Region segmentation**: find the pixels of a region.
  - **Edge segmentation**: find the pixels of its outline contour.

Image Analysis



- Take useful measurements from pixels, regions, spatial relationships, motion etc.
  - Grey scale / color intensity values;
  - Size, distance;
  - Velocity;

HOW MACHINES SEE THE OBJECTS?



“IMAGE” DEFINED

- An image is a 2-Dimensional function f(x,y) where x and y are spatial coordinates, and amplitude f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point.
- When x,y, and f are finite and discrete we call it a digital image.
- Digital image processing means processing/computing digital images using computational means such as using a digital computer.

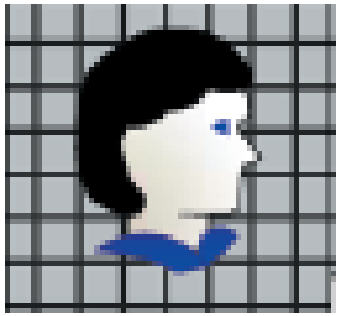


IMAGE FUNCTION & SPATIAL COORDINATES

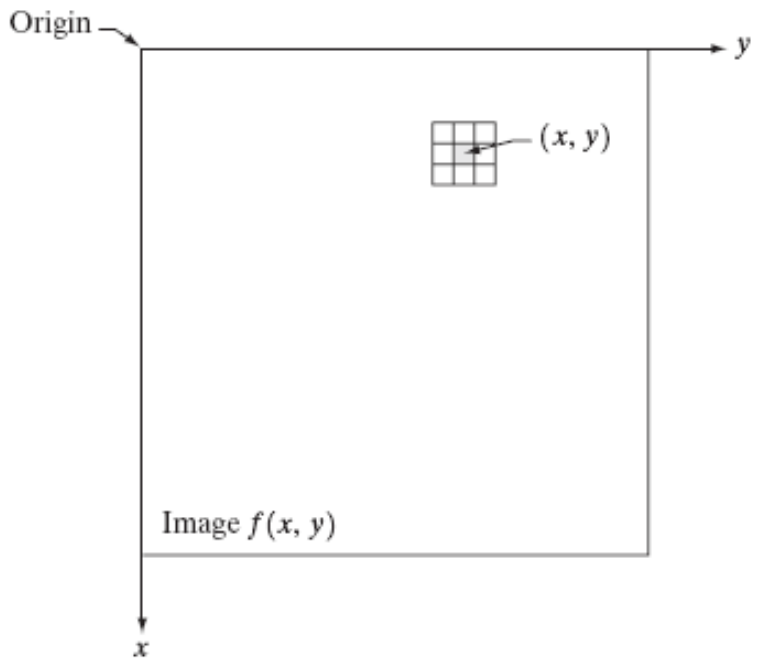


IMAGE FUNCTION & SPATIAL COORDINATES

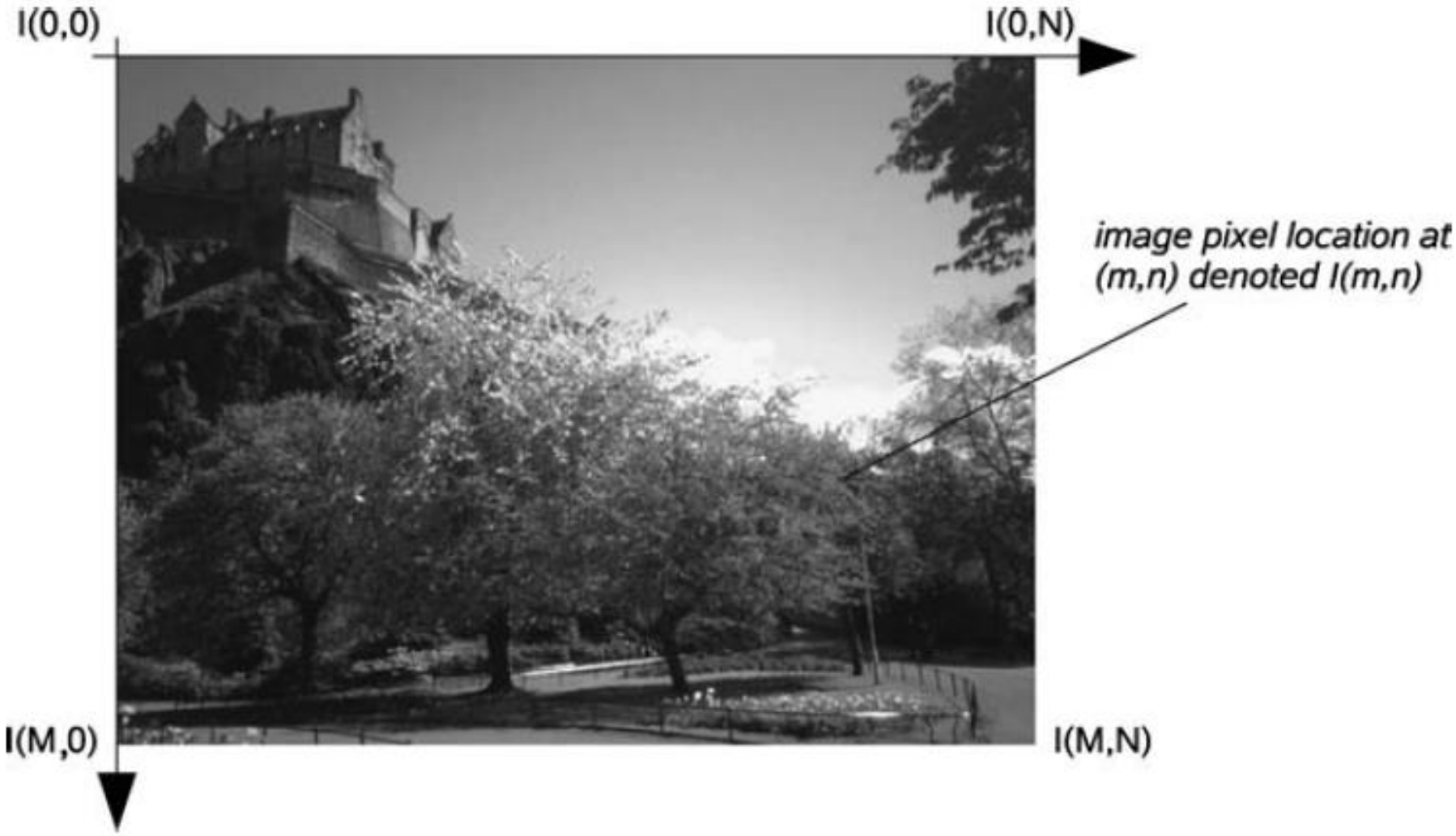


IMAGE COLOR

- An image contains one or more color channels that define the intensity or color at a particular pixel location I (m,n)
- In the simplest case, each pixel location only contains a single numerical value representing the signal level at th

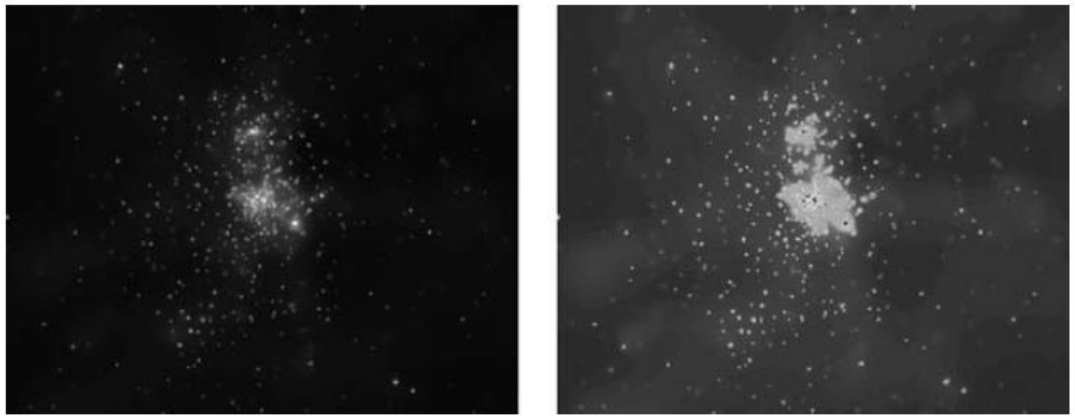
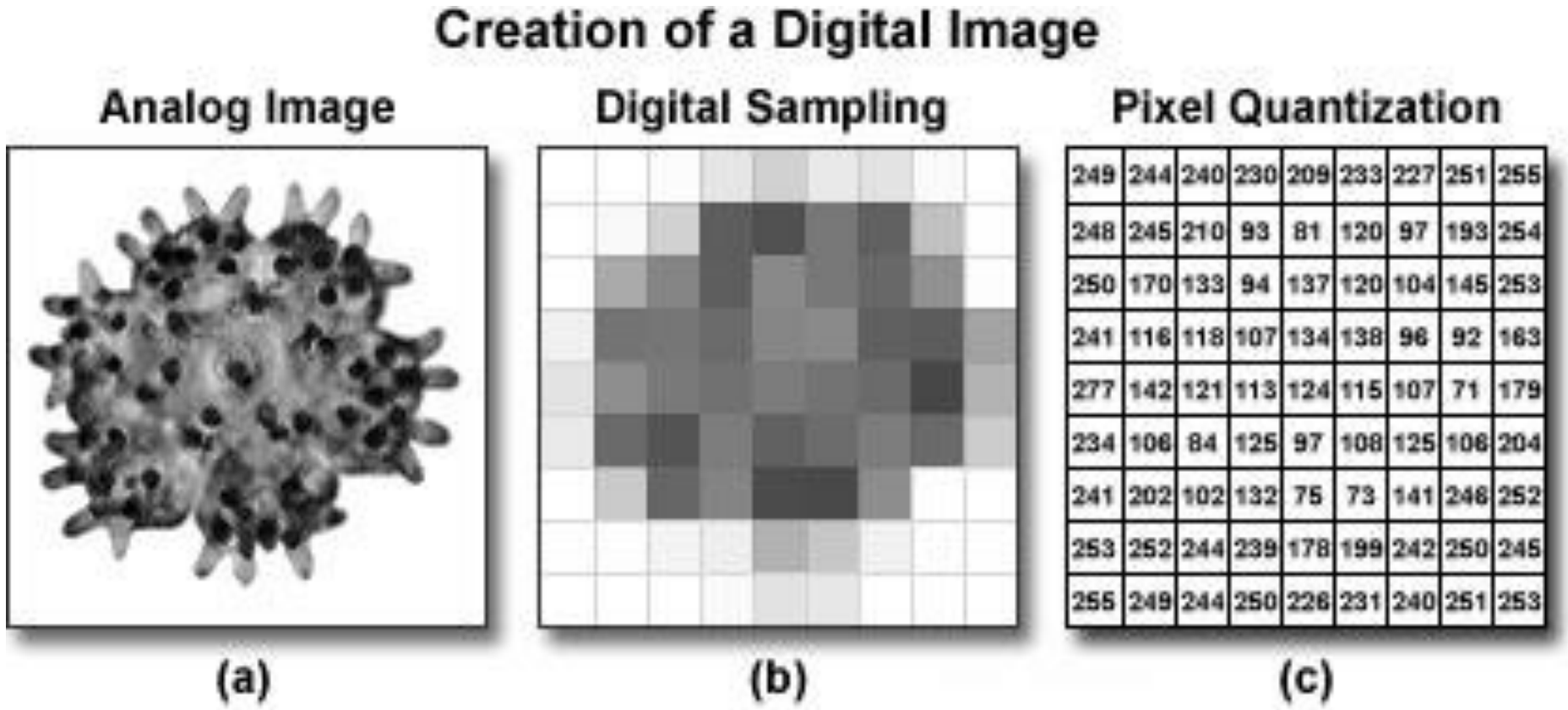


Figure 1.2 Example of grayscale (left) and false colour (right) image display *(See colour plate section for colour version)*

SAMPLING & QUANTIZATION



QUANTIZATION & RESOLUTION

- The size of the 2-D pixel grid together with the data size stored for each individual image pixel determines the spatial resolution and color quantization of the image.
- The representational power (or size) of an image is defined by its resolution.

RESOLUTION

- The resolution of an image source (e.g. a camera) can be specified in terms of three quantities; spatial, temporal, and bit resolution
  - **Spatial resolution:**
    - The column (C) by row (R) dimensions of the image define the number of pixels used to cover the visual space captured by the image.
    - This relates to the sampling of the image signal and is sometimes referred to as the pixel or digital resolution of the image. It is commonly quoted as CxR (e.g. 640x480, 800x600, 1024x768, etc.).

RESOLUTION

- **Temporal resolution**
  - For a continuous capture system such as video, this is the number of images captured in a given time period.
  - It is commonly quoted in frames per second (fps), where each individual image is referred to as a video frame (e.g. commonly broadcast TV operates at 25 fps; 25–30 fps is suitable for most visual surveillance; higher frame-rate cameras are available for specialist science/engineering capture).

RESOLUTION

Bit resolution

- This defines the number of possible intensity/color values that a pixel may have and relates to the quantization of the image information. For instance a binary image has just two colors (black or white), a grey-scale image commonly has 256 different grey levels ranging from black to white whilst for a color image it depends on the color range in use.
- The bit resolution is commonly quoted as the number of binary bits required for storage at a given quantization level, e.g. binary is 2 bit, grey-scale is 8 bit and color (most commonly) is 24 bit.
- The range of values a pixel may take is often referred to as the dynamic range of an image.

HOW IMAGE (VISION) TURNS TO PROCESSING

But the camera sees this:

194	210	201	212	199	213	215	195	178	158	182	2(
180	189	190	221	209	205	191	167	147	115	129	1(
114	126	140	188	176	165	152	140	170	106	78	8
87	103	115	154	143	142	149	153	173	101	57	5
102	112	106	131	122	138	152	147	128	84	58	60
94	95	79	104	105	124	129	113	107	87	69	67
68	71	69	98	89	92	98	95	89	88	76	67
41	56	68	99	63	45	60	82	58	76	74	65
20	41	69	75	56	41	51	73	55	70	63	44
50	50	57	69	75	75	73	74	53	68	59	37
72	59	53	66	84	92	84	74	57	72	63	42
67	61	58	65	75	78	76	73	59	75	69	50

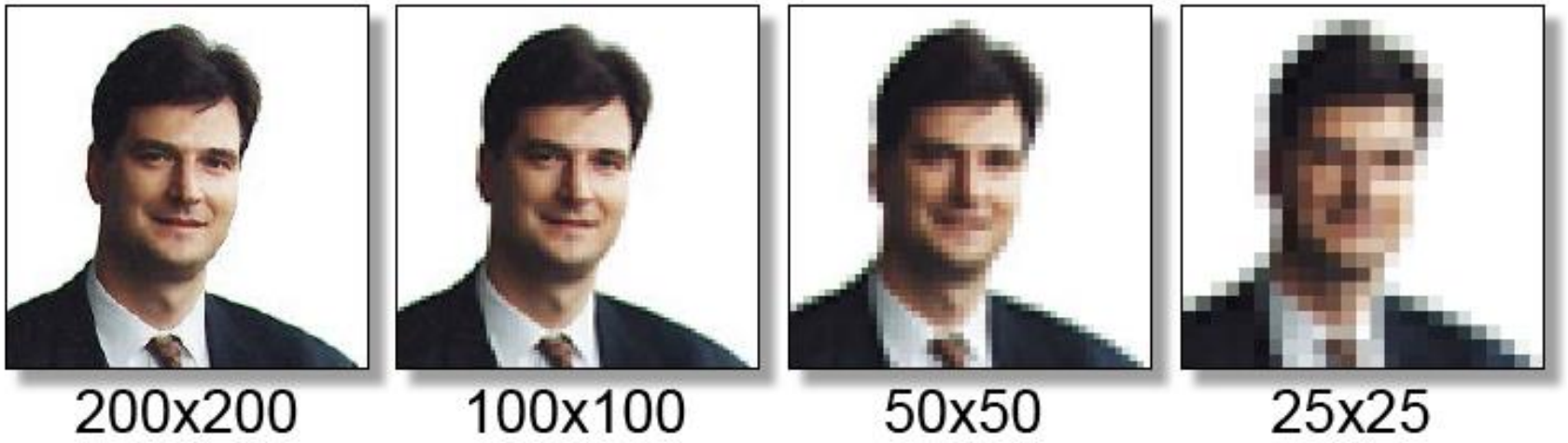
SOME COMMON IMAGE FORMATS AND THEIR CHARACTERISTICS

Format	Characteristics
jpg/jpeg (Joint Photographic Experts Group)	Image compression, supports 8-bit per color (RGB), generational degradation when edited repeatedly.
tiff (Tagged-Image File Format)	Supports 8-bit and 16-bit per color , Support s OCR and device-specific color schemes
Gif (Graphics Interchange Format)	Limited to 256 colors , Supports animation
png (Portable Network Graphics)	16 million colors (truecolor), Good for large images, best suited for editing
bmp (Bit Map)	Simple, suited for all WINDOWS applications, uncompressed

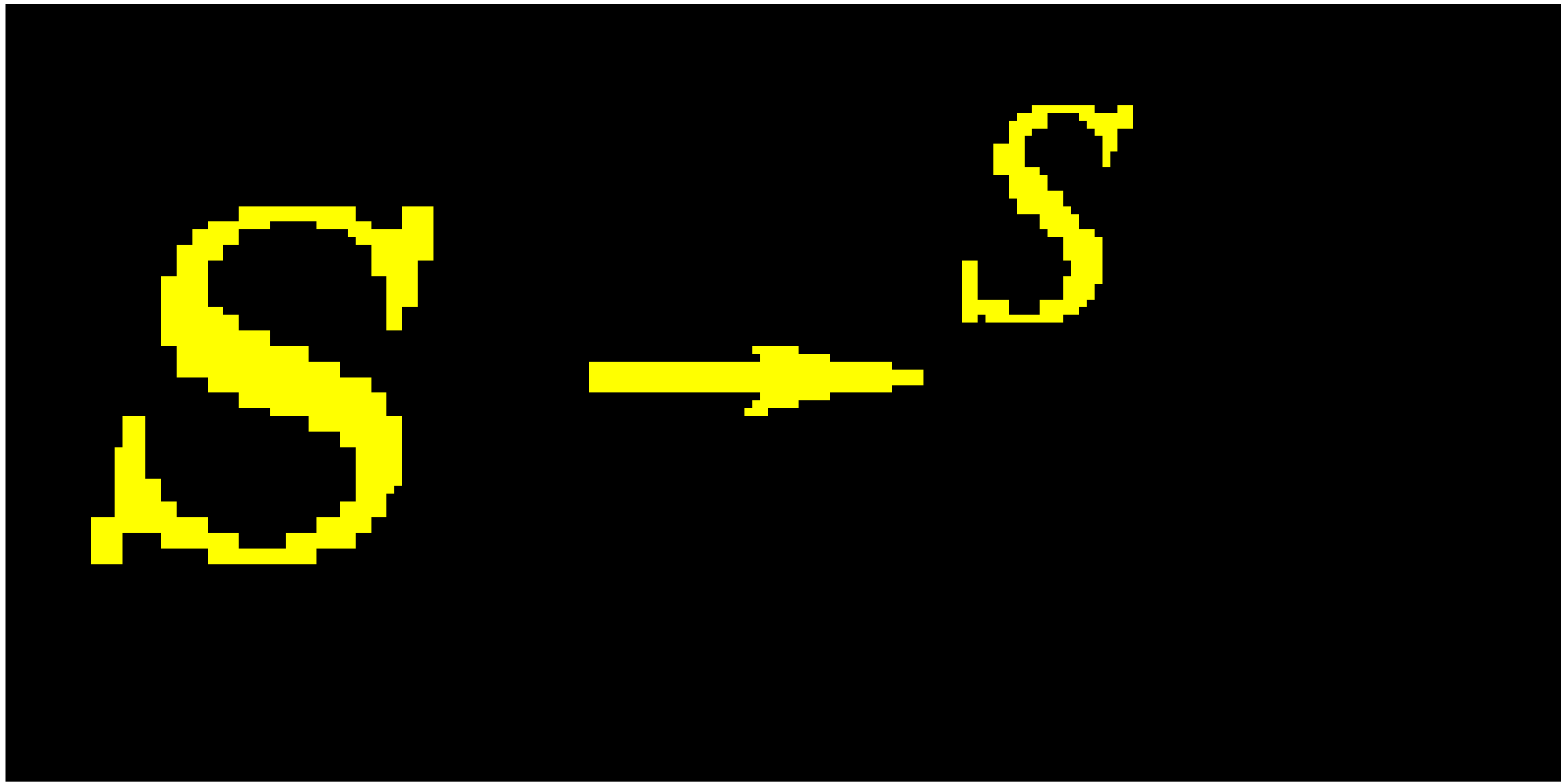
BASIC IMAGE OPERATIONS

CONTRAST ENHANCEMENT

IMAGE RESOLUTION

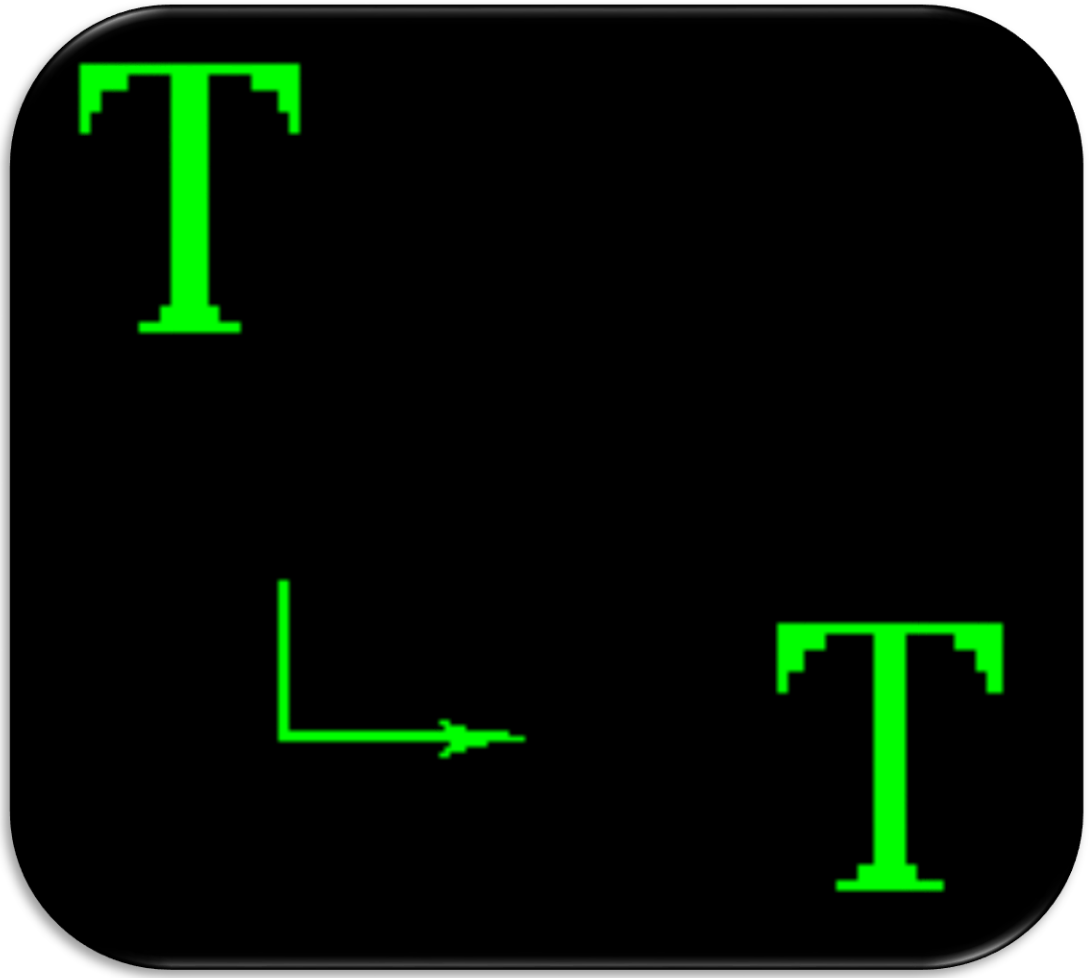


SCALING



ROTATION

TRANSLATE



REFLECT OR MIRRORING

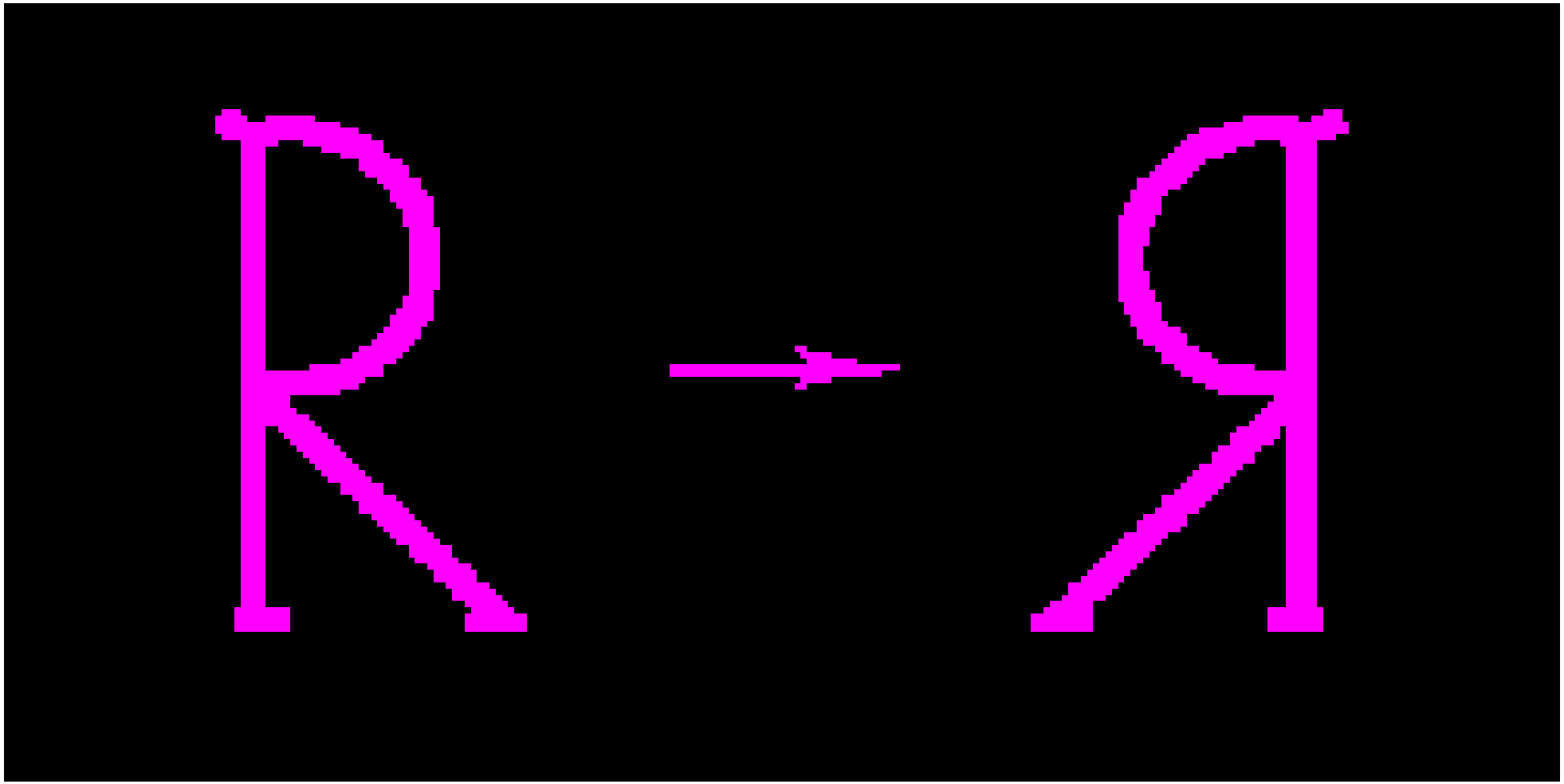
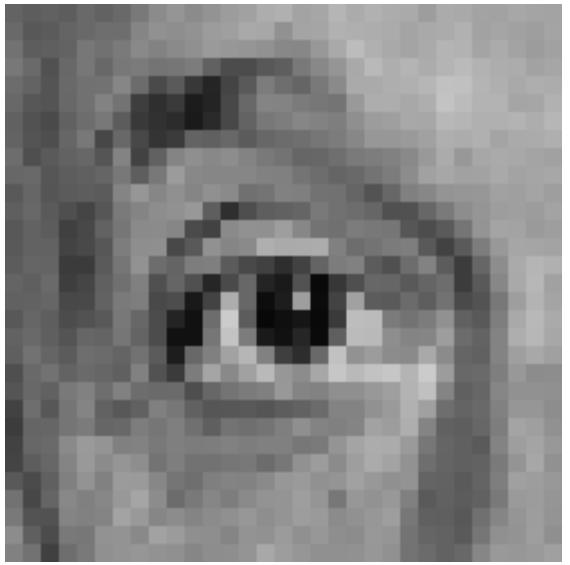
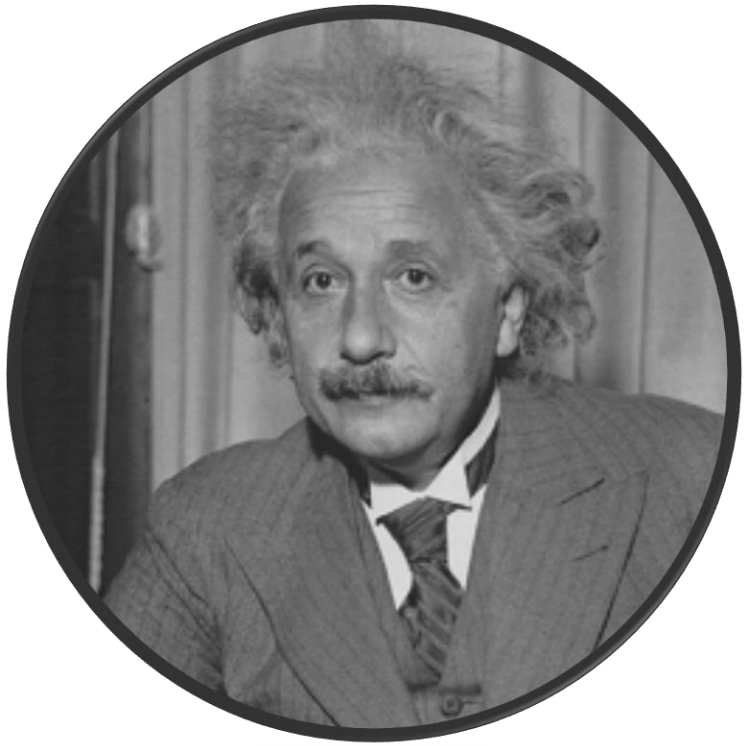


IMAGE SHARPENING



SHARPENING



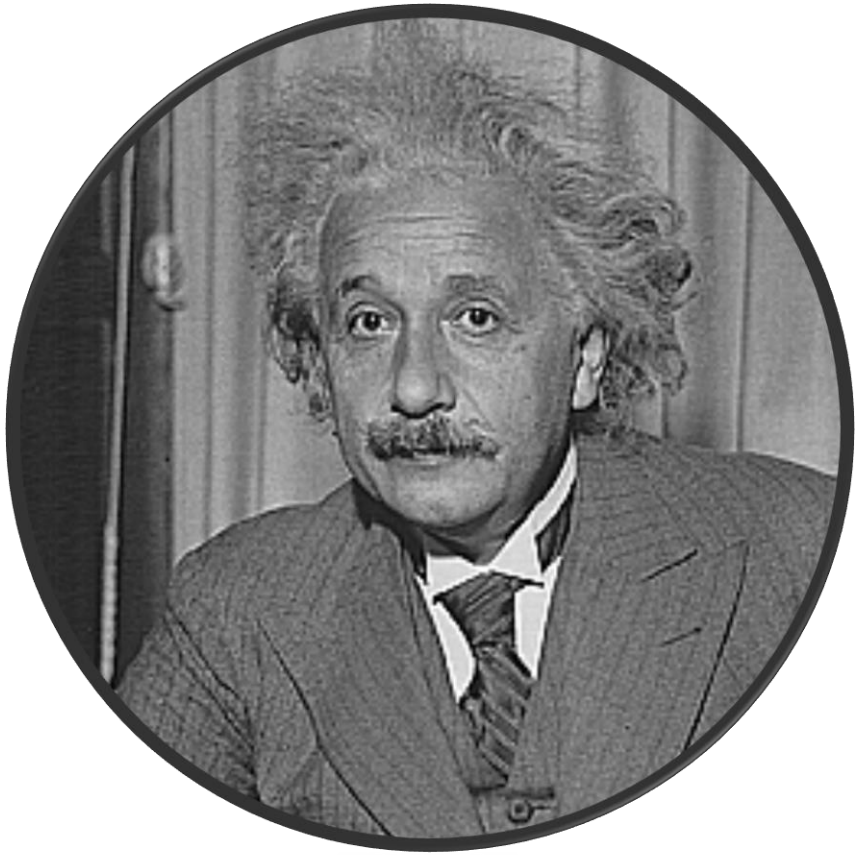
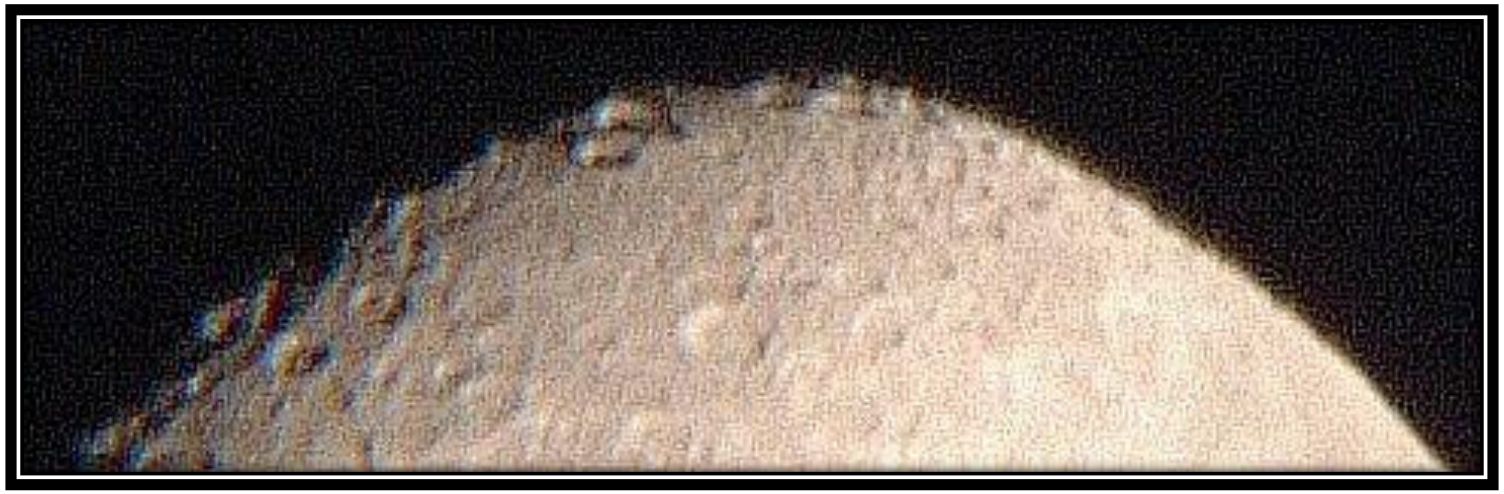


IMAGE SHARPENING



ASSIGNMENT # 01 (SUBMIT BY 17-01-2025 23:59 HRS)

- Use openCV programming codes to perform following (05) image operations:

1. Sharpening of image
2. Rotation
3. Translation
4. Scaling to 2X to 5 X
5. Mirroring

You may use any sample image from Google or other databases for your example.

Email your assignment with code, image input and output to dr.arabbasi74@gmail.com